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N. Navarro-Gonzalez[1], E. Serrano[1], E. Casas-Díaz[1], R. Velarde[1], I. Marco[1], L. Rossi[2] & S. Lavín[1]
1 Servei d'Ecopatologia de Fauna Salvatge, Facultat de Veterinària, Universitat Autònoma de Barcelona, Barcelona, Spain
2 Dipartimento di Produzioni Animali, Epidemiologia ed Ecologia, Università di Torino, Torino, Italy
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Correspondence
Dr Emmanuel Serrano, Servei d'Ecopatologia de Fauna Salvatge, Facultat de Veterinària, Universitat Autònoma de Barcelona (SEFaS-UAB), E-08193, Bellaterra, Barcelona, Spain. Tel:+34 935 868 190; Fax:+34 935 812 006
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Abstract

The European wild rabbit Oryctolagus cuniculus has been recently reclassified as Near Threatened in its natural range in the Red List of Endangered Species by the IUCN, and a huge conservation effort is being undertaken in Spain for this keystone species. Restocking is a frequent measure for wild rabbit population reinforcements and it is also part of predator conservation programmes. However, it can have a negative influence on the resident rabbit population when it is not carried out carefully. In our work, using a model selection procedure based on a theoretic information approach, we analyze which factors favor the presence of sarcoptic mange in some wild rabbit populations in Catalonia (north-eastern Spain), as well as the trend of rabbit abundance in affected and non-affected hunting estates. Presence of mange depends on animal abundance and on restocking numbers (22.09%). From the mean rabbit abundance (30 rabbits hunted km^{-2}) and the mean restocking rate (18 rabbits km^{-2}), the probability of being affected increased in nearly 5% when the restocking rate increased in one unit. Rabbit abundance (2001–2007) depends on the presence of mange and on the effect of the year (23.86%), and clearly declined in the hunting estates with mange, whereas abundance is maintained in mange-free zones. Our results indicate that a sanitary control is necessary when restocking wild rabbit populations. Furthermore, restocking is shown to be a potential way of introducing pathogens to resident populations, especially under conditions of high density.

Introduction

The introduction of parasites represents a clear threat for the local fauna (Ricciardi & Simberloff, 2009) and many of those examples are attributed to introduced pathogens decimating naïve populations (Prenter et al., 2004). Parasite introductions are often attributable to human activities, with the introduction of exotic species being the most common procedure in a wide range of taxa, for example the infestation of native fishes by the trematode Bucephalus polymorphus carried by introduced zebra mussels Dreissena polimorpha in the Great Lakes (Vitule, Freire & Simberloff, 2009) or the parapoxvirus infection of red squirrels Sciurus vulgaris due to the introduction of infected American gray squirrels Sciurus carolinensis in England and Wales (Dunn, 2009). However, little is known regarding the role of other activities such as restocking or population supplementation in the introduction of parasites (Tompkins, Draycott & Hudson, 2000).

The European wild rabbit Oryctolagus cuniculus is an important game species in Spain and also a keystone species in the Mediterranean ecosystem (Delibes-Mateos, Ferreras & Villafuerte, 2009). In the Iberian Peninsula, rabbit populations have declined sharply over the past century. Two viral diseases (myxomatosis and rabbit hemorrhagic disease), together with hunting pressure, change in agricultural habits and other factors, have contributed to the decline (Delibes-Mateos et al., 2007). As a consequence, the European wild rabbit has been reclassified in the Red List of

Endangered Species by the IUCN since 2008 as Near Threatened in its natural range (IUCN Red List, 2008). Sarcoptic mange Sarcoptes scabiei has been reported recently for the first time in rabbits in some hunting states in Mallorca, [Balearic Islands, Spain (Milla´ n, 2010)]. The origin of the disease and the consequences on rabbit population are still unknown. In the present article, we describe the first record of a sarcoptic mange outbreak in free-ranging wild rabbits in the Iberian Peninsula following restocking orientated towards local population reinforcements. In Spain, rabbits are restocked in large numbers, mainly for hunting purposes, but also as part of predator conservation programs, such as those in favor of the critically endangered Iberian lynx Lynx pardinus or the threatened Spanish imperial eagle Aquila adalberti (Moreno et al., 2003; Delibes-Mateos et al., 2007). It has been estimated that nearly 500 000 rabbits are released each year in Spain and France (Ward, 2005). In this work, we aim to illustrate the fact that the combination of the population abundance of each hunting estate together with the intensity of restocking predisposed to the presence of mange. We also describe the population trend in mange-affected versus non-affected hunting estates.

Material and methods

Study area

The study area is located in north-eastern Spain, within the Tarragona province (4117$_0$N, 0157$_0$E), and its climate is typically Mediterranean (Fig. 1). The coastline is a popular tourist destination, but the inland remains as a semi-rural zone where agriculture plays an important role. The predominant landscape is cultivated areas (fruit trees and cereals) with typical Mediterranean scrubland patches. Hunting is a popular and a traditional activity, with rabbit and red-legged partridge Alectoris rufa being the main game species. A total of 50 hunting estates were included in our study area, covering a total surface of 81 080 ha, the surface range of individual estates varying from 56 to 5567 ha.

Rabbit abundance and mange presence

Our data were based on hunting statistics (hunted rabbitskm$_{-2}$) as an abundance index. Hunting bags have been recorded in this province since the hunting season 2001–2002 until 2007–2008, and the number of animals restocked each year in each hunting estate was also available. To allow comparison between hunting estates, our data were categorized as animals hunted and animals released per square kilometer (restocking rate). Hunting statistics have been used as abundance estimation in several species of vertebrates (Danell & Ho¨ rnfeldt, 1987; Nichols, Lancia & Lebreton, 2001; Cattadori et al., 2003), including the wild rabbit in Spain (Virgo´ s, Cabezas-Dı´ az & Lozano, 2007). The presence of sarcoptic mange was first detected in 2002 when a rabbit with characteristic skin lesions, thick gray-brown crusts with fissures in the hind limbs (Pence & Ueckermann, 2002) was hunted. The disease was easily confirmed by skin scraping and a direct microscopic examination of the mites (Arlian, 1989). After the first case was confirmed, a field investigation was carried out and hunters, rangers and experienced technical staff of the study area were informed and asked to look for and report the presence or absence of the disease in their hunting estates. Further cases were considered positive or negative only by visual examination, because sarcoptic mange can easily be identified macroscopically.

Data analyses

The probability of a hunting estate having sarcoptic mange (absence or presence) was related to rabbit abundance and the number of animals released per surface unit. To reduce the effect of outliers and stabilize the relationship between mean and variance, the response variables were transformed logarithmically (Zuur, Ieno & Smith, 2007). Because environmental factors that can affect rabbit population dynamic such as temperature and precipitation (Calvete et al., 2004) were unknown, the game season of each year (autumn–winter) was included in the model as a random factor. However, it was later excluded as it did not improve the selected model. The relationship between the presence or absence of sarcoptic mange with the explanatory variables was studied by a general linear model (GLM) using a binomial distributed error with a logistic link function.

Population abundance dependence on mange and temporal abundance trends in affected estates versus nonaffected estates were studied using a general additive model (GAM). This model is more appropriate than linear regression for data that do not show a clear linear relationship between the response variable and the explanatory variable (Wood, 2006). This kind of statistical modeling has been used to analyze population trends in rabbits (Virgo´ s et al., 2003). In some hunting estates, the yearly abundance of rabbits was unavailable; thus for the population trend analysis, we used those hunting estates (n=28, representing a total surface of 39 206 ha) that recorded rabbit densities for the entire study period.

Combining the studied explanatory variables, we performed several statistical models with biological meaning.

For example, because the demographic effects of sarcoptic mange tend to be density dependent (Pence & Ueckermann, 2002; Rossi et al., 2007), and restocking a higher number of animals increases the probability of introducing a pathogen (Fenichel et al., 2008), we fitted three different models including rabbit abundance, number of animals restocked per km^2 (as fixed factors) and their addition for explaining the presence of sarcoptic mange in the affected estates. In the second analysis, we evaluated whether the population trend was influenced by the year, a determining factor of the rabbit abundance according to Virgo´ s et al. (2003), by the presence of mange, their additive effect and their

Figure 1 The study area is represented by the shaded shape in the

interaction. Then, we selected the best model following the theoretic information approach based on Akaike's Information Criterion corrected for small sample sizes (AICc), AICc differences (DAICc) and Akaike weights (Wi) (Anderson, Burnham & White, 2001; Johnson & Omland, 2004). Briefly, competing models are ranked by their Akaike differences (Di) from the best model, which has the lowest AIC. When Di was o2 units, we chose models with the fewest parameters. Subsequently, we estimated the Akaike weight (W_i), the relative probability that each model is the best model among those being compared (Burnham & Anderson, 2002). In this procedure, the null model (that includes only the intercept) was also included as a competing model. Once the best model was selected, we confirmed the general assumptions of the fitted models (mainly the absence of a residual pattern) by analyzing the residuals (Zuur et al., 2007). In order to determine the effect size, we calculated the explained deviance (ED) of the best model. As this value includes the deviance shared by the model's variables, we calculated it and obtained the pure deviance of each of the variables. Finally, we reported preliminary baseline values of both rabbit abundance and restocking for predicting the probability of mange, fitting a classification tree (De'ath & Fabricius, 2000). All statistical analyses were performed using R version 2.9.2 (R Development Core Team, 2010); the additive models were implemented in the 'mgcv' library, whereas tree models were implemented in the 'tree' library of the statistical package of R.

Results

The presence of mange was explained (ED=22.09%) by the model that included the additive effects of both rabbit abundance ($b_{population\ abundance}$=2.91, 1.82 – 4.08 95% CI) and the number of rabbits restocked per surface ($b_{restocking\ rate}$=3.51, 1.90 – 5.24 95% CI, $AICc_{population\ abundance+restocking\ rate}$= 276.45; W_i=1). After partitioning the ED in its components (Legendre, 1998; Zuur et al., 2007), we obtained the pure effect of the abundance and the number of animals restocked for explaining the presence of mange: 8.19 and 5.49%, respectively, supporting the importance of both factors in the probability of being infected. About 9%of the ED was shared by both factors, supporting the fact that some hunting estates with intense game activity carry out restocking even at high population densities. From the mean rabbit abundance (30 rabbits hunted km$_{_2}$) and the mean restocking rate (18 rabbitskm$_{_2}$), the probability of being affected increased in nearly 5% when the restocking rate increased by one unit. As an example, in Fig. 2, we represented the probability of mange in two contrasting situations of rabbit abundance.
To explain the temporal abundance changes in the hunting estates, the best model (AICc=_26.94, W_i=1), which included the interaction between the year of harvesting and mange, explained 23.86% of the rabbit abundance in the hunting estates.
After 2002, when sarcoptic mange was first detected, rabbit abundance in affected hunting estates decreased considerably (Fig. 3). The population in these estates increased during 2005, but did not achieve the abundance values found before the sarcoptic mange outbreak. Conversely, non-affected estates initially had a lower rabbit abundance, which was maintained during the study period without wide fluctuations. Restocking strategy was constant over years. Therefore, we can relate the variations in our abundance index to real variations in animal abundance.
On the other hand, our classification tree procedure showed that hunting estates were affected by sarcoptic

Figure 2 Effect of restocking rate on the probability of a hunting state of being affected by sarcoptic mange Sarcoptes scabiei in both high- (430 rabbits hunted km$_{_2}$, solid line) and low-abundance (o30 rabbits hunted km$_{_2}$, dashed line) hunting estates.

Figure 3 Rabbit population trends in both affected and mange-free hunting estates. Dots represent the mean abundance and bars represent their standard errors.

mange when the abundance was higher than 43 rabbits huntedkm$_{_2}$ and the restocking rate was higher than 4.67 rabbitskm$_{_2}$ (44 observations were misclassified, classification rate=0.843).

Discussion

Given the ease to capture, raise and breed European wild rabbits, restocking with captive-bred animals or translocations from other areas has been one of the main focuses of rabbit conservation in Spain (Ward, 2005). However, several studies suggest that restocking is not an effective management strategy (Delibes-Mateos et al., 2007). It can even lead to negative consequences such as spreading rabbit hemorrhagic disease and myxomatosis (Ward, 2005), impacting on the complex social and genetic structure of the resident rabbit population (Catala´ n, Rodrı´ guez-Hidalgo & Tortosa, 2008) or decreasing some donor populations (Ward, 2005). Although in our study area restocking was implemented by hunters for reinforcing local populations, we have shown the relationship of this measure with the introduction of a parasitic disease. Additionally, considering that we included in our analysis hunting estates that may have acquired mange following its natural expansion and not by restocking, the influence of restocking on the presence of mange may be even higher. It is also noteworthy that there are evidences of a certain decline in rabbit populations of mange-affected estates, while non-affected estates maintained rabbit abundance during the study period. Although during the study period no other pathogen (e.g. myxomatosis or rabbit hemorrhagic disease) was suspected of being responsible for this trend, our work did not explore the potential role of other additional factors (e.g. micro-habitat alterations, see Virgo´ s et al., 2003).

Most of the restocked wild rabbits in the study area (about 60%, unpubl. data) were captive reared and this most likely increased the possibility of introducing sarcoptic mange into this previously mange-free population. In domestic rabbit farms, sarcoptic mange is not a rare disease, and it is related to farm factors such as hygienic status (Rosell, 2000). However, sarcoptic mange does not appear in the bibliography as a wild rabbit disease (Gorta´ zar et al., 2000). Thus, we deem that the original focus was possibly triggered by releasing captive-reared animals, and that the additional foci that appeared soon later in distant places (as far as 17 km, despite high habitat fragmentation) were caused by translocation of captured rabbits from the initial affected zone. Further release of captive-reared animals can contribute to the establishment of the disease as endemic and prevent its control; indeed, continued restocking possibly alters the normal population dynamics after an epidemic wave, which leads to a reduction in population numbers and, as a consequence, a reduced disease prevalence and probability of transmission. In Britain for example, the annual release of a large number of pheasants to supplement harvested stocks is probably responsible for maintaining or increasing the burden of Heterakis gallinarum year after year (Draycott et al., 2000). Because wild rabbit is now a Near Threatened species (IUCN Red List, 2008) in its native range, care should be taken when animals are translocated for any purpose. Captive-reared animals, even those belonging to the wild type, are prone to carry pathogens if not bred in optimal sanitary conditions. A good example of this is the role of livestock with low sanitary surveillance on several mange outbreaks in some populations of wild ungulates (Ferna´ ndez-Mora´ n et al., 1997; Leo´ n-Vizcaı´no et al., 1999; Gonza´ lez-Candela, Leo´ n-Vizcaı´no & Cubero-Pablo, 2004).

Sarcoptic mange has an additional importance: it is a zoonosis and can also affect several other mammal species (Pence & Ueckermann, 2002). It has affected endangered species, such as the Eurasian lynx Lynx lynx, (Mo¨ rner, 1992; Ryser-Degiorgis et al., 2002) or the Arctic fox Alopex lagopus, (Mo¨ rner, 1992) and was responsible for the local decrease of some endemic wild ruminants such as the Iberian wild goat Capra pyrenaica, (Leo´ n-Vizcaı´no et al., 1999) or the Cantabrian chamois Rupicapra pyrenaica parva, (Ferna´ ndez-Mora´ n et al., 1997). Although the agent shows a certain host specificity, its introduction into the wild poses a risk for the host population and other sympatric species, specially close relative ones, since inter-specific transmission has occurred in the wild (Mo¨ rner, 1992).

Another factor facilitating the presence or spread of sarcoptic mange, as we have seen in our analyses, is high rabbit abundance. Sarcoptic mange tends to be density dependent, as it is transmitted by direct and indirect contact (Pence & Ueckermann, 2002). High density, in general, can facilitate the occurrence of diseases, but little is known regarding the link between density and diseases in lagomorphs. In fact, this group appears to be less affected by overabundance-related disease problems than others (Gorta´ zar et al., 2006).

Animal supplementation (as defined by the IUCN/SSC Re-introduction specialist group, 1998) is a frequent measure in animal conservation programs (Fischer & Lindenmayer, 2000), and has became common in managed hunting areas. However, introduced animals can be asymptomatic carriers of both common (Woodford & Rossiter, 1993) and exotic pathogens (Viggers, Lindenmayer & Spratt, 1993) representing an unexpected exposure for the native population. Even avirulent forms of common pathogens carried by released animals can become virulent into the new environment (Woodford & Rossiter, 1993). Thus, disease risks are associated with any kind of animal movement (Ballou, 1993; Griffith et al., 1993; Woodford & Rossiter, 1993; Fevre et al., 2006), and there are several examples that illustrate this fact, even related to conservation projects (Woodford & Rossiter, 1993; Deem, Karesh & Weisman, 2001).

Our results indicate that rabbit restocking has the potential to introduce a dangerous parasite such as S. scabiei, with negative demographic consequences on the resident population and immensurable impact on other species (e.g. predators). Thus, to avoid this undesirable impact of parasite introduction, a strict sanitary control is required when implementing animal releases, especially in conservation programs based on population supplementation.

However, at present, it is not possible to rule out that mange had formerly affected these wild rabbit populations. Thus, both serological retrospective studies and genetic characterization of the mite need to be carried out to determine the disease origin.

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References

Anderson, D.R., Burnham, K.P. & White, G.A. (2001). Kullback–Leibler information in resolving natural resource conflicts when definitive data exist. Wildl. Soc. Bull. 29, 1260–1270.

Arlian, L.G. (1989). Biology, host relations and epidemiology of Sarcoptes scabiei. Annu. Rev. Entomol. 34, 139–161.

Ballou, J.D. (1993). Assessing the risks of infectious-diseases in captive breeding and reintroduction programs. J. Zoo Wildl. Med. 24, 327–335.

Burnham, K.P. & Anderson, D.R. (2002). Model selection and multimodel inference: a practical information-theoretic approach. 2nd edn. New York: Springer Verlag.

Calvete, C., Estrada, R., Angulo, E. & Cabezas-Ruiz, S. (2004). Habitat factors related to wild rabbit conservation in an agricultural landscape. Landsc. Ecol. 19, 531–542.

Catala´ n, I., Rodrı´ guez-Hidalgo, P. & Tortosa, F.S. (2008). Is habitat management an effective tool for wild rabbit (Oryctolagus cuniculus) population reinforcement? Eur. J. Wildl. Res. 54, 449–453.

Cattadori, I.M., Haydon, D.T., Thirgood, S.J. & Hudson, P.J. (2003). Are indirect measures of abundance a useful index of population density? The indirect case of red grouse harvesting. Oikos 100, 439–446.

Danell, K. & Ho¨ rnfeldt, B. (1987). Numerical responses by

populations of red fox and mountain hare during an outbreak of sarcoptic mange. Oecologia 73, 533–536.
De'ath, G. & Fabricius, K.E. (2000). Classification and regression trees: a powerful yet simple technique for ecological data analysis. Ecology 81, 3178–3192.
Deem, S.L., Karesh, W.B. & Weisman, W. (2001). Putting theory into practice: wildlife health in conservation. Conserv. Biol. 15, 1224–1233.
Delibes-Mateos, M., Ferreras, P. & Villafuerte, R. (2009). European rabbit population trends and associated factors: a review of the situation in the Iberian Peninsula. Mammal Rev. 39, 124–140.
Delibes-Mateos, M., Redpath, S.M., Angulo, E., Ferreras, P. & Villafuerte, R. (2007). Rabbits as a keystone species in southern Europe. Biol. Conserv. 137, 149–156.
Draycott, R.A.H., Parish, D.M.B., Woodburn, M.I.A. & Carroll, J.P. (2000). Spring survey of the parasite Heterakis gallinarum in wild-living pheasants in Britain. Vet. Rec. 147, 245–246.
Dunn, M.A. (2009). Parasites and biological invasions. Adv. Parasitol. 68, 161–184.
Fenichel, E.P, Tsao, J.I., Jones, M. & Hickling, G.H. (2008). Fish pathogen screening and its influence on the likelihood of accidental pathogen introduction during fish translocations. J. Aquat. Anim. Health 20, 19–28.
Ferna´ ndez-Mora´ n, J., Go´ mez, S., Ballesteros, F., Quiro´ s, P., Benito, J.L., Feliu, C. & Nieto, J.M. (1997). Epizootiology of sarcoptic mange in a population of cantabrian chamois (Rupicapra pyrenaica parva) in Northwestern Spain. Vet. Parasitol. 7, 163–171.
Fevre, E.M., Bronsvoort, B.M.D.C., Hamilton, K.A. & Cleaveland, S. (2006). Animal movements and the spread of infectious diseases. Trends Microbiol. 14, 125–131.
Fischer, J. & Lindenmayer, D.B. (2000). An assessment of the published results of animal relocations. Biol. Conserv. 96, 1–11.
Gonza´ lez-Candela, M., Leo´ n-Vizcaı´no, L. & Cubero-Pablo, M.J. (2004). Population effects of sarcoptic mange in barbary sheep (Ammotragus lervia) from Sierra Espun˜ a Regional Park, Spain. J. Wildl. Dis. 40, 456–465.
Gorta´ zar, C., Acevedo, P., Ruiz-Fons, F. & Vicente, J. (2006). Disease risk and overabundance of game species. Eur. J. Wildl. Res. 52, 81–87.
Gorta´ zar, C., Villafuerte, R., Ferna´ ndez de Luco, D., Cooke, B.D., Jorda´ n, G., Page´ s, A., Feliu, C., Angulo, E. & Luciente, J. (2000). Enfermedades del conejo silvestre. In Enfermedades del Conejo Tomo II: 455–512. Rosell, J.M. (Ed.). Madrid: Mundi-Prensa Libros.
Griffith, B., Scott, J.M., Carpenter, J.W. & Reed, C. (1993). Animal translocations and potential disease transmission. J. Zoo Wildl. Med. 24, 231–236.
IUCN Red List. (2008). Available at http://www.iucnredlist.org/details/41291/0 (accessed August 2009).
IUCN/SSC Re-introduction specialist group. (1998). Guidelines for re-introductions. Gland: IUCN.
Johnson, J.B. & Omland, K.S. (2004). Model selection in ecology and evolution. Trends Ecol. Evol. 19, 101–108.
Legendre, L. (1998). Numerical ecology. 2nd edn. Amsterdam: Elsevier Science.
Leo´ n-Vizcaı´no, L., Ruiz de Iba´ n˜ ez, M.R., Cubero, M.J., Ortiz, J.M., Espinosa, J., Pe´ rez, L., Simo´ n,M.A. & Alonso, F. (1999). Sarcoptic mange in Spanish ibex from Spain. J. Wildl. Dis. 35, 647–659.
Milla´ n, J. (2010). First description of sarcoptic mange in wild European rabbit (Oryctolagus cuniculus). Eur. J. Wildl. Res. 56, 455–457.
Moreno, S., Villafuerte, R., Cabezas, S. & Lombardi, L. (2003). Wild rabbit restocking for predator conservation in Spain. Biol. Conserv. 118, 183–193.
Mo¨ rner, T. (1992). Sarcoptic mange in Swedish wildlife. Rev. Sci. Tech. OIE 11, 1115–1121.
Nichols, J.D., Lancia, R.A. & Lebreton, J.D. (2001). Hunting

statistics: what data for what use? An account of an international workshop. Game Wildl. Sci. 18, 185–205.
Pence, D.B. & Ueckermann, E. (2002). Sarcoptic mange in wildlife. Rev. Sci. Tech. OIE 21, 385–398.
Prenter, J., MacNeil, C., Dick, J.T.A. & Dunn, M.A. (2004). Roles of parasites in animal invasions. Trends Ecol. Evol. 19, 385–390.
R Development Core Team 2.9.2. (2010). A language and environment for statistical computing. Vienna: R Foundation for Statistical Computing. Available at http://www.Rproject.org (accessed March 2010).
Ricciardi, A. & Simberloff, D. (2009). Assisted colonization is not a viable conservation strategy. Trends Ecol. Evol. 24, 51–59.
Rosell, J.M. (2000). Enfermedades del conejo. Madrid: Mundi-Prensa.
Rossi, L., Fraquelli, C., Vesco, U., Permunian, R., Sommavilla, G.M., Carmignola, G., Da Pozzo, M. & Meneguz, P.G. (2007). Descriptive epidemiology of a scabies epidemic in chamois in the Dolomite Alps, Italy. Eur. J. Wildl. Res. 53, 131–141.
Ryser-Degiorgis, M.P., Ryser, A.M, Bacciarini, L.N., Angst, C. & Gottstein, B. (2002). Notoedric and sarcoptic mange in free-ranging lynx from Switzerland. J. Wildl. Dis. 38, 228–232.
Tompkins, D.M., Draycott, R.A.H. & Hudson, P.J. (2000). Field evidence for apparent competition mediated via the shared parasites of two game bird species. Ecol. Lett. 3, 10–14.
Viggers, K.L., Lindenmayer, D.B. & Spratt, D.M. (1993). The importance of disease in reintroduction programs. Wildl. Res. 20, 687–698.
Vitule, J.R.S., Freire, C.A. & Simberloff, D. (2009). Introduction of non-native freshwater fishes can certainly be bad. Fish. Fish. 10, 98–108.
Virgo´ s, E., Cabezas-Dı´ az, S. & Lozano, J. (2007). Is the wild rabbit (Oryctolagus cuniculus) a threatened species in Spain? Sociological constraints in the conservation of species. Biodivers. Conserv. 16, 3489–3504.
Virgo´ s, E., Cabezas-Dı´ az, S., Malo, A., Lozano, J. & Lo´ pez-Huertas, D. (2003). Factors shaping European rabbit abundance in continuous and fragmented populations of central Spain. Acta Theriol. 48, 113–122.
Ward, D. (2005). Reversing rabbit decline. One of the biggest challenges for nature conservation in Spain and Portugal. Technical report published by SOS Lynx and the IUCN Lagomorph Specialist Group. Available at http://www.ualberta.ca/_dhik/lsg/report_lynx_rabit.pdf (accessed August 2009).
Wood, S. (2006). Generalized additive models: an introduction with R. Boca Raton: Chapman & Hall/CRC.
Woodford, M.H. & Rossiter, P.B. (1993). Disease risks associated with wildlife translocation projects. Rev. Sci. Tech. OIE 12, 115–135.
Zuur, A.F., Ieno, E.N. & Smith, G.M. (2007). Analysing ecological data. New York: Springer.